PALAEOMAGNETISM AND PETROCHEMISTRY OF BHOWALI VOLCANICS (BHIMTAL AREA)

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It gives me pleasure to certify that "Palaeomagnetism and Petrochemistry of Bhowali Volcanics (Bhimtal area)" is the original contribution of Mr. Mukhtar Ahmad, to which he is submitting the dissertation for the award of the degree of Master of Philosophy in Geology of this University. It has not been published in part or full anywhere else.

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PREFACE

The present investigations accompany the Palaeomagnetic and Petrochemical studies of Bhowali- Bhimtal volcanies of Permocarboniferous age in Kumaon Himalayas.

Though the area is complicated Geologically and structurally. The sampling was carried out with utmost caution. The rocks show weak magnetization and stable directions. The Geomagnetic poles were compared with the Geomagnetic poles of other Permocarboniferous rocks.

Petrochemical studies were also carried out to know the nature of the Volcanic suite.

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Chapter -I

INTRODUCTION

I-1 Palaeomagnetism

Most of our information regarding geomagnetic field has been obtained by direct recording at magnetic observations over the past 400 years. Palaeomagnetism provides the means to extend this record into remote geological past.

All rocks which contains oxides and sulphides of iron exhibit magnetic properties. Hence the rock specimens behave as a magnet. With a north and south pole and a magnetic axis. This magnetisation is a naturally occuring property and is reffered to a FOSSIL MAGNETISM, or NATURAL PREMANENT MAGNETISATION. Palaeomagnetism is a loose term which is used by some workers to denote the study of this property, were as others use it to signify the property itself.

In some cases the fossil magnetism was imprinted when the rock was formed, its axis being along the direction of the magnetic field at that time. It may therefore serve as a fossil compass useful for determining the diretion of the ancient Geomagnetic field.

Further its intensity depends in a complex wy on the strength of the field in which it was aquired, so that in principal the intensity as well as the direction can be investigated.

Most Palaeomagnetic work have however been concerned with investigating the variation in direction of the ancient field.

I-2 Geomagnetic Field

The present Geomagnetic field resembles that of a dipole field situated at the earth's centre. The lines of force of such a field runs from South to North. This is dipole is called as INCLINED GEOCENTRIC DIPOLE and its axis makes an angle of 11.5 degrees with the rotation axis. The studies of present earth field is a magnetic force vecter F, measured at a time which is known from observatory clocks to an accuracy of seconds. Where as the datum of Palaeomagnetism is magnetisation vector M, which may reflect the ancient field direction at a time estimated to a geological time scale. Therefore it is necessory making this comparisons to use some working model which expresses the long term behaviour rather than its short term detailed behaviour. The model used is that of a Geocentric dipole field.

I-3 Magnetic Minerals

Most rock forming minerals do contribute to fossil magnetism and are referred to as NON MAGNETIC MINERALS. The fossil is due to the iron oxides and sulphides present as accessory minerals and they are called as MAGNETIC MINERALS. The minerals responsible for the magnetic properties of the rocks are predominantly within the ternary system $FeO-TiO_2-Fe_2O_3$. Other relevant minerals are pyrhotite and oxyhydroxides of iron.

I-4 General History of Palaeomagnetism

The great majority of Palaeomagnetic observation have been published since 1950, on the Mt, Etnalavas which still stands an observation of great value. Alexander Humboltd in (1997) carried out the magnetic survey of mountain top of Palatinate, and found northerly aspect showing southpole and southerly aspect showing north poles And he remarked that it was not likely that lightening has caused these magnetisation.

The intensity of these magnetisation occasionally found in rock exposures was continued during the 18th century by many workers. In these occurrences variously called PUNTI DISTINI or POINT ISOLES, is the magnetisation direction varied from points to points in the same exposure.

And this was the first phenomena to attract attention In the middle of the 19th century such instruments were developed which were sensitive sufficiently to measure much weaker magnetised rocks.

Delessi (1949) showed that certain recent laves were magnetized parallel to the earth magnetic field. Melloni(1953) studied that direction of Natural Remanant magnetisation of of lavas of Mount Vensuvious and Phlegraean fields which was roughly parallel to the present field. He further showed that when specimens are raised to red heat in the laboratory they acquired the magnetisation parallel to the present field. This led Melloni to believe that magnetisation were acquired parallel to the earths field. Folgerhaitar extended Melloni's study and he also studied the magnetization of pottery and brickes. Bruhnes and David have studied about reverssals, and further evidences on reversals was prodused by Mercanton (1926, 1932, 1932).

I-5 Types of Magnetization

(A) Thermoremanent Magnetization

The Thermoremanent Magnetization of a rock is theremanence acquired upon cooling through a certain temperature interval in the presence of a magnetic field. The remanence acquired during coòling from the maximum curie point to the room temperature is called Thermoremanent Magnetization

(B) Chemical Remanent Magnetization

Many rocks contain magnetic minerals which were formed either at low temperature by chemical processes initially or have been subjected to secondry alterationat temperature below the curie points. And these effects may take a variety of formes. As the term chemical remanent magnetization is used to embrace all types of remanence (including chemical remanence) which arise from chemical or physico chemical change, occuring at temperature below curie points.

(C) Detrial Remanent Magnetization

A small proportion of the particles which go to form deterital sediments are usually magnetic. The particles have been derived by erosion from older rocks and many inherit a remanence from them. Under suitable depositional conditions it is possible that magnetic moments of these particles become statistically aligned along the direction of the ambient field. And this aligment is the Detrital remanent magnetization.

(D) Viscous Remanent Magnetisation

This is concerned with the effects which can be observed in the laboratory in the course of a few hourse. Over longer time spans remanence may be effected in two ways and commonly both will operate. First the intensity of primary magnetisation may decay in time a process which is called Viscous magnetisation or Viscous decay. Secondly a new magnetization may be acquired at temperature below the curie point and this is called Viscous remanent Magnetisation.

I-6 Geophysical and Geological Aspects of Palaeomagnetism

Palaeomagnetism has made a substantial contribution to the problem of geology and geophysics. It is mainly helpful in the problem of stratigraphic correlation especially in rocks where fossil evidances are lacking. And in tectonically disturbed rocks. From the knowledge of the fossil magnetism. It is possible to study the palaeomagnetic spectrum of a particular type of deposit chosen and this may be compared against the spectrum of modern deposit of similar type. The studies of Palaeomagnetism is also intimately connected with the problem of palaeogeography.

It also helps in calculating the past position of land masses relative to the earth pole and to each other. Such distribution studies provide a test of hypothesis of polar wandering and continental drift. By the method which is independent of any geological evidence. It is the only method by which the intensity of earth's magnetic field of the past can be determined. As well as it is helpful in solving many other geological and geophysical problems.

I-7 Earlier Work

The observed Indian Palaeomagnetic results enables appreciation of Mesozoic - Tertiary volcanism in the Peninsular India. As also the magnitically stratigraphic grouping of Gondwana sediments. The Phanerozoic data yield a systematic deduction of solar wandering and drift pattern of Indian land mass. Comparison of Phanerozoic data from southern land mass is made for a Palaeomagnetic reconstruction of Gondwana land. These data suggests the fragmentation of Gondwana super continent commenced some time in late Jurassic- early Cretaceous, and that a substantial part of a drift process was over by the late Eocene - Oligocene times.

Considerable Palaeomagnetic investigation have now been done on Indian rocks ever since Irving (1956) conducted the first cursury sampling of some Deccan lavas of Igatpuri in Western Ghats.

Chapter - II

II-1 General

Kumaon Himalayas include 320 kilometer strech of mountains which lies between the Sutlej in the west and Kali river at the western border of Nepal in the east structurally and stratigraphically the Kumaon Himalayas are the direct continuation of the eastern Punjab Himalayas.

Inspite of the considerable work done on the Kumaon Himalayas it is still one of the most inspiring place of the geology on our globe, and remains unsolved. The four fold division of the Kumaon Himalayas are as follows.

(A) Sub Himalayas

(B) Lower Himalayas

(C) Higher Himalayas

(D) Tibetian Himalayas

The four fold division is applicable better in Kumaon than in Punjab Himalayas.

(A) Sub Himalayas of Kumaon

This include the foot hills belt having Tertiary deposits only. And the foot hills are narrow. The lower Miocene Murry types of deposits have disappeared here and the change is relatively abrupt sout east of sutlej river and coincides with a southward bulge of the lower Himalayas. Characterised by the Krol thrust from the krol region to the south east along the Himalayan range. The foot hill belt is entirely built of Siwalik sediments. And the Eocene beds are over siwaliks. Siwaliks of Kumaon are divided into lower middle and upper.

New investigations have shown that only small remanents of middle to upper Siwalik are actually present. In the eastern foot hills lower Siwaliks are well exposed along the Kathgotham-Nainital road. They consists of variegated(violet, red and green) clays and partly calcareous sandstone. And here the Siwaliks show abnormal cross structures. It seems that lower Himalayan thrust is overiding an structural and erosional gap in Siwaliks. Towards the thrust zone sandstones become quartzitic.

The upper Siwalik of Himalayas are preserved just east of Sutlej, west and east of Ganges river and between the Ganges foot hills of Nainital. The contacts between upper middle and lower Siwaliks are faulted along strike faults paralleling the foot hills of Punjab himalayas. And despite strong folding and faulting steep thrusting the Siwalik sediments practically everywhere are normal.

(C) Lower Himalayas

Almost complete absence of fossils in the lower Himalayas leaves many stratigraphical problems unsolved. Since upto now correlation had been based on lithology only. In the Kumaon lower Himalayas we distinguish the Krol belt stretching from the Simla region to the northwest of Nainital in south east.

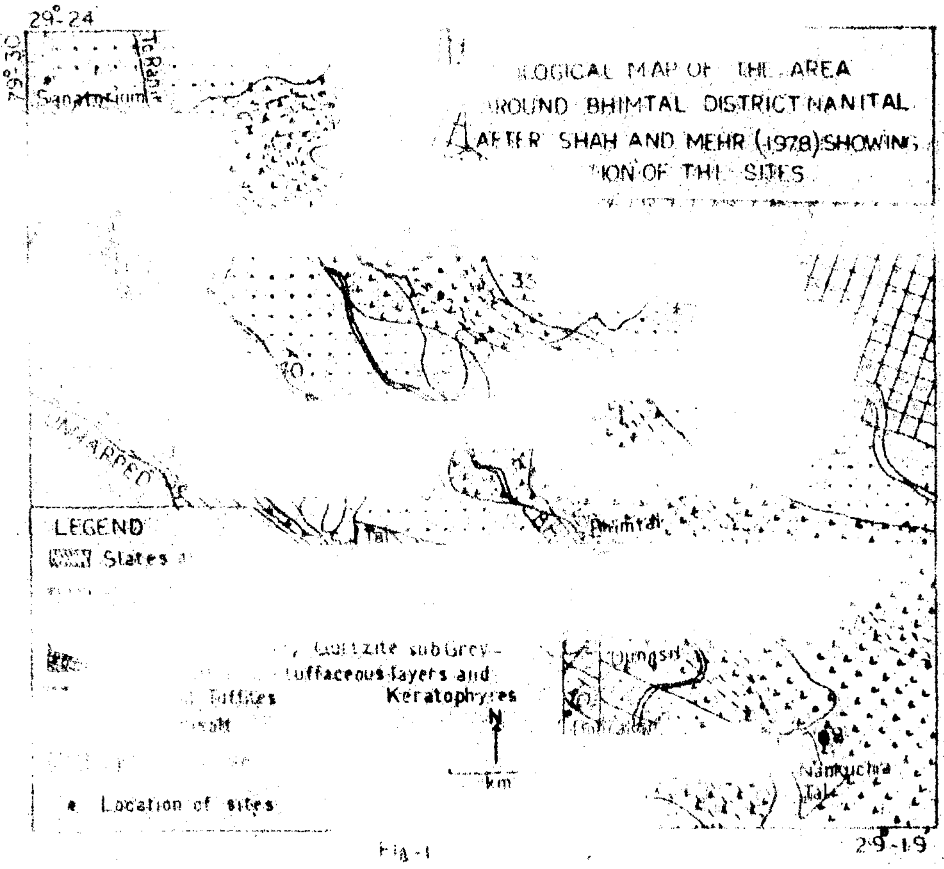

29°24
79°30
Sanatorium
LOGICAL MAP OF THE AREA
ROUND BHIMTAL DISTRICT NANITAL
AFTER SHAH AND MEHR (1978) SHOWING
ION OF THE SITES
35
70
UNMAPPED
LEGEND
States
Tal
Bhimtal
Quartzite sub Grey-
tuffaceous layers and
Tuffites
Keratophyres
salt
N
km
Location of sites
Naukuchia
Tal
29°19

Fig.-1

rocks makes a northwestern-southeastern anticline structure which is typically exhibited by quertzite and its two limbs and beneath the quartzites lie the volcanic rocks which occupy the core of the anticline. To the west and northwest of this anticline occur a sequence of sediments that have been correlated with krol and Infrakrol by almost all the workers. And which at Nainital makes a large syncline. The rocks to the northeast were taken as comprising Nagthats and older rocks. The absence of Krol and Infrakrol to the northeast was explained by postulating a northwest - southeast thrust.

According to Heim and Gainser et al (1939) and Gansser et al (1964) this thrust constitutes the north and southern limb of synformally folded South Almora thrust. They have marked the thrust south of Ramgarh, and north dipping south Almora thrust occurs further north of Ramgarh and extends along Bhikiasen and Mukteshwar.

Raina and Dungrakoti et al (1975) suggests physical continuity of porphyries of Ramgarh upto Amritpur and Ranibagh and there is no structural discordance between the Ramgarh porphyry and underlying Bhimtal formation. As the porphyries of Ramgarh continu southward and into the volcanics of Bhimtal (Shah & Mehr et al 1978). Which arespilitic in nature according to Vatdharagan et al 1974. Rao et al 1974, Shah and Mehr (1976). According to them rocks of Ramgarh are also keratophyric and are genetically related to the spilites of Bhimtal.

II-3 Structural Geology

Structural geology of Bhimtal Bhowali area have been put forward in particular by Shah and Mehr 1978, mainly on the basis of mapping the metasediments. Keeping in mind the structure of adjacent areas.

The chronology of tectonic events according to Shah and Mehr 1978 is ass follows:

1. Folding that gave rise to the main Bhowali Bhimtal anticline (F-1). This was an upright fold with subhorizantal axis and the plane extending almost north west - southeast.
2. East west folding super imposed over the main anticline(F-2).
3. Krol thrust.
4. Gentle northeast - southwest flexture (F-3).
5. North-south transverse faults.

The Bhowali Bhimtal anticline belongs to this fold episode which was developed at the time of the folding of Almora thrust sheeting Almora Baijnath synforms and originally extends northwest-Southeast. The cleavages developed in the thin Argillaceous layers in quartzites are due to the flexuralship which are parallel to the bedding.

II-4 Stratigraphy

Shah and Mehr 1978 have modified the stratigraphy of this area. They have divided upper Paleozoic sequence of this area into two distinct lithostratigraphic units. The lower part comprising volcanic, volcanogenic and other associated sediments including the Keratophyres and limestones of Ramgarh have been designated as "Bhimtal - RAMGARH FORMATION" and equated with Blaini. The upper part forming a thic successio of quartzite, sandstones and variegated slates, predominantly black in colour is included in the Nainital formation. And the stratigraphic succession suggested for the Bhimtal Bhowali area and to the north east is as follows

Quartzites with variegated slates - lower part of the: INFRA
Nainital formation KROL

.......Upradi thrust............. South Almora thrust

Purple, gray, green slates and quartzite (with keratophyres at Ramgarh) Lensoid dolomitic limestone and occassional spilitic flows Bouldry graywacke Foliated basic volcanics (spilites, tuffes, and tuffites)	BHIMTAL RAMGARH FORMATION

II-5 Age of the Formation

Most of the workers have considered the quartzites and slates of Bhowali to be of Nagthat age. And taking the volcanics of the area to be contemporaneous lava flows and tuffs. Auden (1934) places the Nagthat in the Devonian age. Olham (1888) the late Devonian age of the Nagthat formation belonging to the Jaunsar series.

While Shah and Mehr et al (1978) have divided the upper Paleozoic sequence of this area into two distinct divisions. The lower part comprising volcanics, volcanogenic and other associated sediments including the keratophyres of Ramgarh as well as the limestones of the same age. and equated this lower part with Blaini which according to Auden et al (1934) is of carboniferous age. While Hyden and Heron give Permian age for Blaini.

According to Shringarpur and Desai ( ) Limestones just south of Bhowali has yielded a poorly preserved fauna, identified as species of Fenestella probably of middle Carboniferous age. On the basis of this fauna found Shah and Mehr suggests Blaini age of the rocks of the Bhimtal and Bhowali area rather than Nagthat. As there is no unconfirity between Blaini and Infrankrol Raina and Dungrakoti also suggests Blaini age for all the rocks between volcanic and Infra-krol.

Chapter - III

COLLECTION OF SAMPLES, INSTRUMENTS, & EXPERIMENTAL PROCEDURE

IV-1 Collection of Samples

Samples were collected from number of sites. Most of the sites were chosen along the road cuttings, hill sides nallas and streams to avoid the weathering effects. Oriented samples with the help of clinometre compass and the sprit level were collected. These samples were reoriented and cored in the laboratory. About three to five samples from each site of the size of about 6 inches in length, 4 inches high and were collected with north direction and downside marked

The sites were chosen in such a way that there were no apparent disturbance and effect of weathering. In view of this undisturbed samples could be collected. However from each site 3 to 5 oriented samples were collected mostly at regular distances from each site.

A total of ninteen sites could be sampled. The oriented block collected were around sixty five. However some of the sites have to be rejected as the spesimens show weak magnetisation. From each sample four to eight specimens of 1inch diameter and 1.75 inches in length were obtained for the measurement of natural remanent directions with Astatic magnetometre. Similar to that of (Creer 1969) of the sensitivity 10^{-6} emu/mm.

III-2 Astatic magnetometre

Astatic magnetómetre is a magnetic set up having two very sensitive magnets aligned in antiparallel direction. And when the spesimens is kept below the magnetometer the magnet reacts to the vertical gradient of the spesimens. Giving direction of the magnetisation in X, Y and Z components of earths geomagnetic field with reference to the north. Regarding the structure of the magnetometer, it is a system of two magnets fixed to a vertical rod which is suspended by a phosphobromse wire. The magnetometer are of equal magnetic moments which are set with three direction of magnetisation horisamtal and antiparallel with a distance above the other a small mirror fixed to a rod produses an image of illumination on a scale permitting angular deflection of the suspended system about which a vertical axis is to be measured.

In paleomagnetic studies a specimen is brough from a large distance to a position close below the lower magnet The equilibrium deflection prodused by the resultent torque is measured. The magnetic field prodused by the specimens at the lower and upper magnets will be approximately in the inverse ratio of the cubes of the difference.

III-3 General desctiption of the apparatus

The magnetometer building (30x13 feet) is constru ted from non magnetic materials with its length parallel to the magnetic Meridian. The accessories like, tripod, specimen table and set of three pairs of Helmholts coils are screwed to the floor in the north west corner of the room while the Instrument control are fixed to the table in the opposite corner.

The magnetic system is suspended by a phosphobronze strip in side an alluminium tube fixed to a triangular plate. The table is held vertically with the help of levellings screws on the plate. The bottom of the tube is closed by an alluminium damping disk. The system is suspended with the south pole of the lower magnet pointing to the north The optical system consists of a 4 mm square mirror glued to the rod holding the two magnets, a projector and a millimeter scale at 2.5 meters from the magnetometer. An alluminium table permits the displacement of the specimens under the magnetometer.

III-4 Helmholts Coil System

By using a system of Helmholts coils. Measurements can be made in a nearly field free space independent of magnetic activity in the earths field. Three pairs of coils of radius. 72,68, and 64 inches respectively are set perpendicular to each other and compensate for the east-west (D) north-south(H) and the vertical (Z) components of the magnetic field. Each coil has two windings of 100 turns. The first winding are used to compensate for the mean value of the earths field. at the location Currents of .51 ampere in the Z coilsand .14 ampere in the H coils are required to compensate for the vertical component of .6 oersted and a horizontal component of .14 oersted since the coil system is alligned along the magnetic meridian the east west component is zero and the first winding of D is left unused.

Fluxgate system

The second winding are used to compensate for changes in the magnetic field such as daily variation. The compensation is done automatically by a fluxgate system, basically the electrical recording magnetometer.

III-4 A.C. Demagnetisation Apparatus

The demagnetisation set up is composed of two Demerstate to control the passing currents in the coils fixed around the revolving accessory.

The set up consists of voltmeter which enables the specimens to be cleaned at different peak fields of the current Abattery and three pairs of Helmholtz coils are fixed to cancel the earths field while cleaning the specimens. The main purpose of the A.C. demagnetisation set up is to cancell and clean the th secondry components.

III-5 Experimental Procedure

After obtaining the required size of the specimens the natural remanent direction were measured for each specimens on the Astatic magnetameter. Then a suitable specimens having the magnetic direction quite close and similar to that of other specimens were chosen almost from each sample for pilot cleaning. And these specimens were chosen almost from each sample for pilot cleaning. And these specimens were subjected to A.C. peak fields of 25, 50, 75, 100, 150, 200, 300, 400, 500, and 600 oersted. After a peak field was chosen for batch cleaning of the specimens of each site on the basis of the fall of the intensity and the particular peak field having the direction quite close to other peak fields of the pilot cleaning.

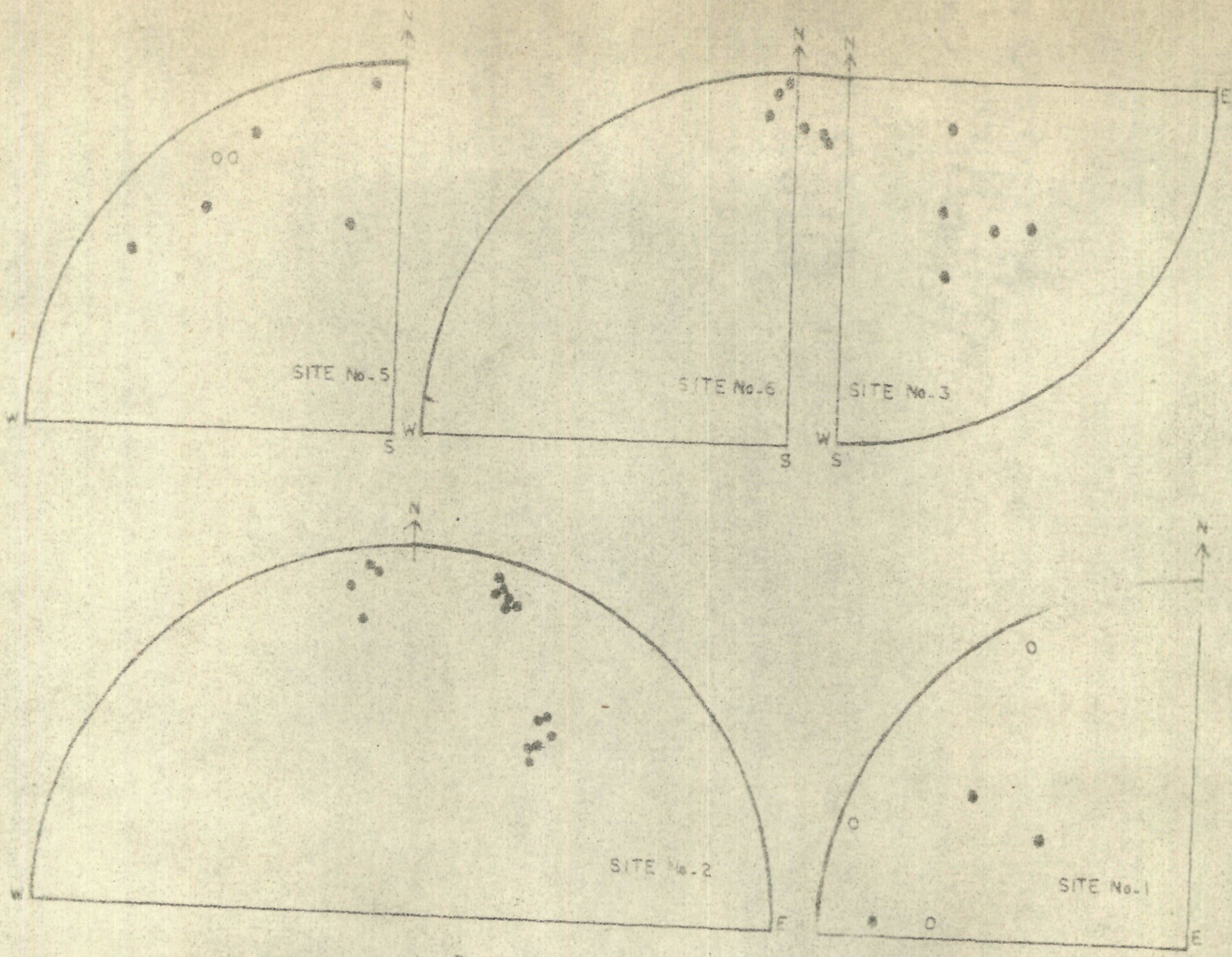


Fig-3

● DOWN DIP
○ UP DIP

STEREOGRAPHIC PROJECTIONS OF MAGNETICALLY CLEANED DIRECTIONS OF MAGNETIZATION FROM SITES 1, 2, 3, 5, 6

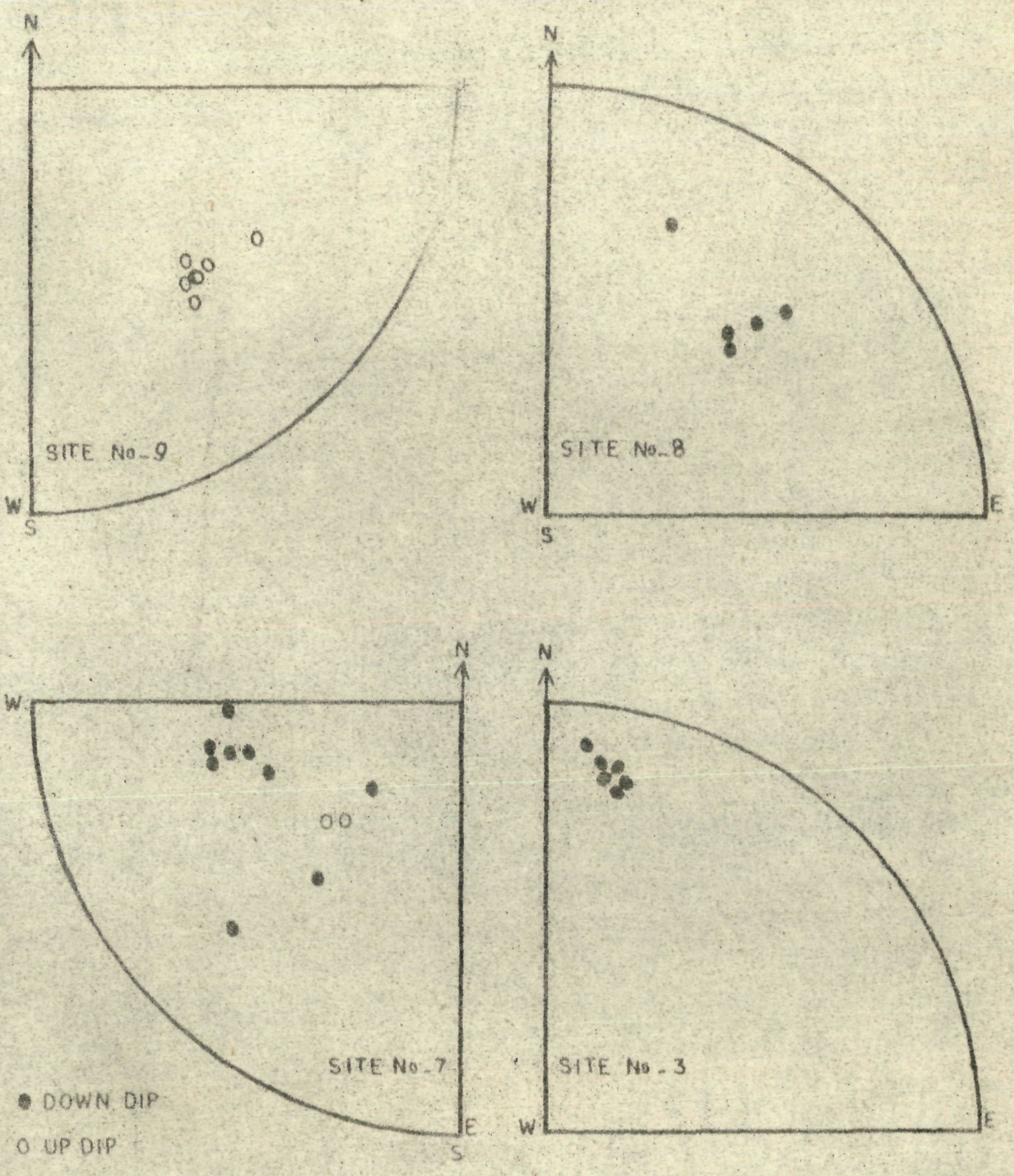


Fig. 4 STEREOGRAPHIC PROJECTIONS OF MAGNETICALLY CLEANED DIRECTIONS OF MAGNETIZATION FROM SITES-3-7-8-9.

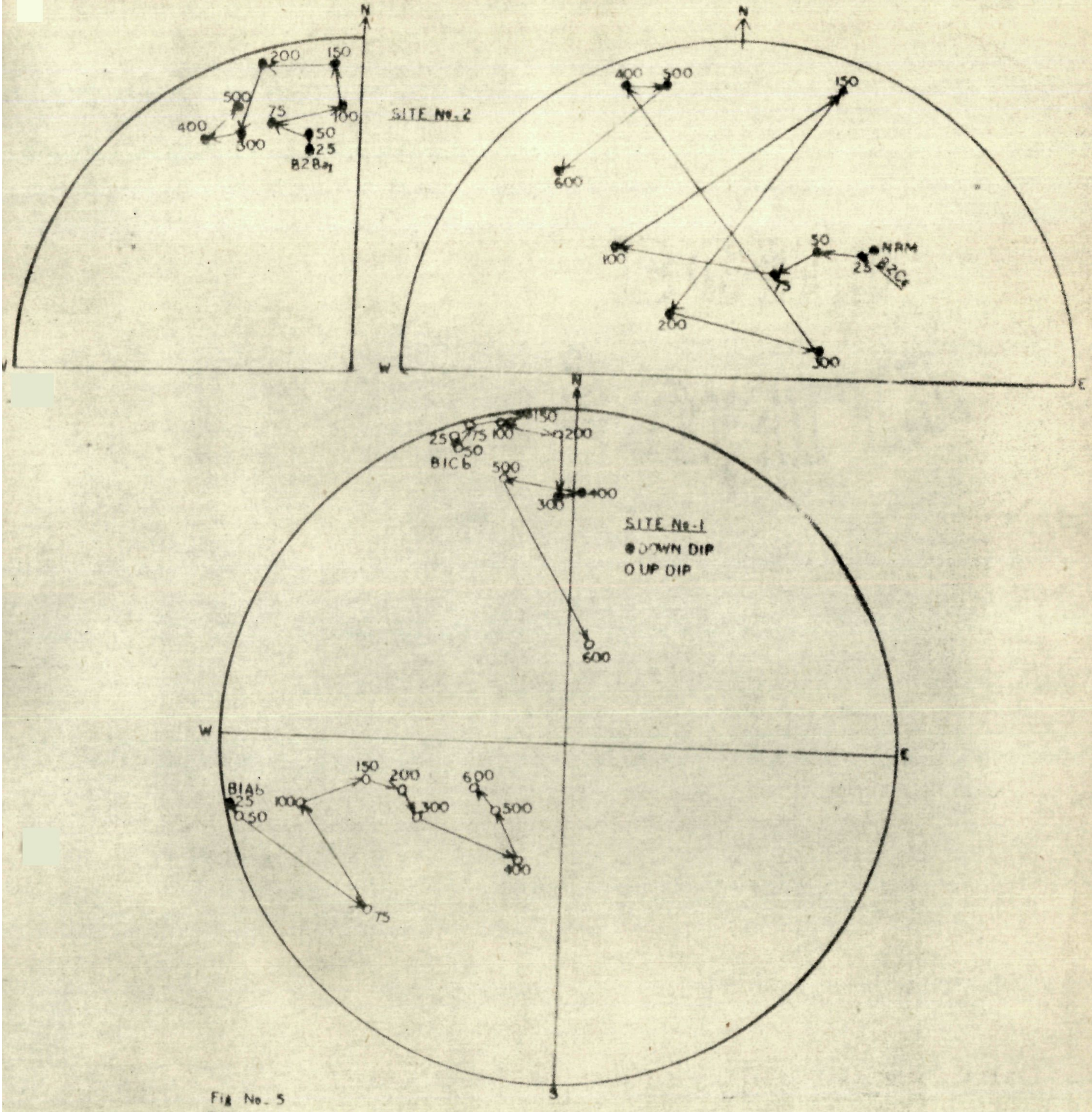
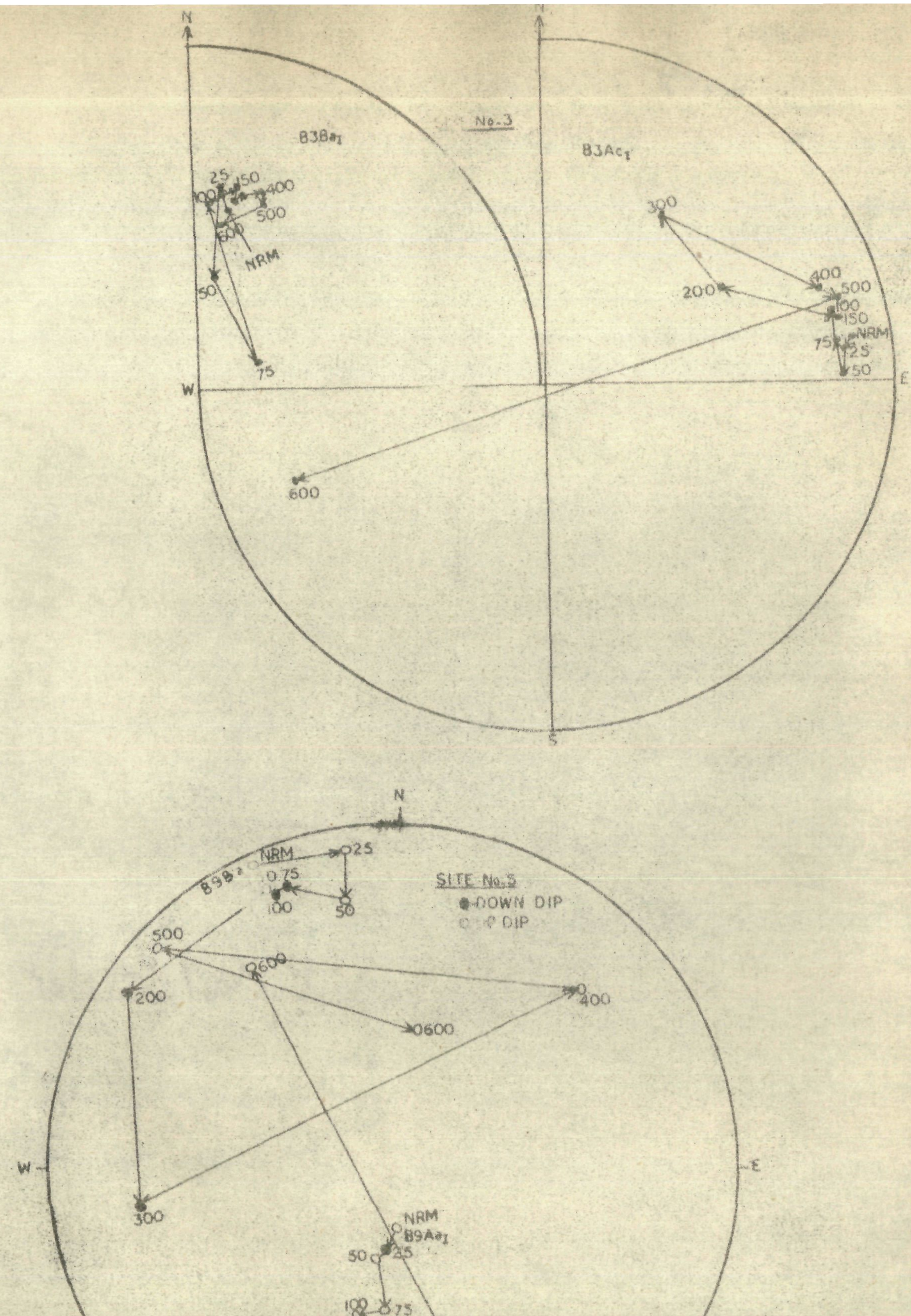


Fig No. 5
EQUAL AREA PROJECTIONS SHOWING CHANGES IN DIRECTIONS OF MAGNETIZATION AFTER CLEANING IN VARIOUS PEAK A.C FIELDS FOR SPECIMENS OF SITES 1 & 2



AL AREA PROJECTIONS SHOWING CHANGES IN DIRECTIONS OF MAGNETIZATION
CLEANING IN VARIOUS PEAK A.C FIELDS FOR SPECIMENS OF SITES _ 3&5

28

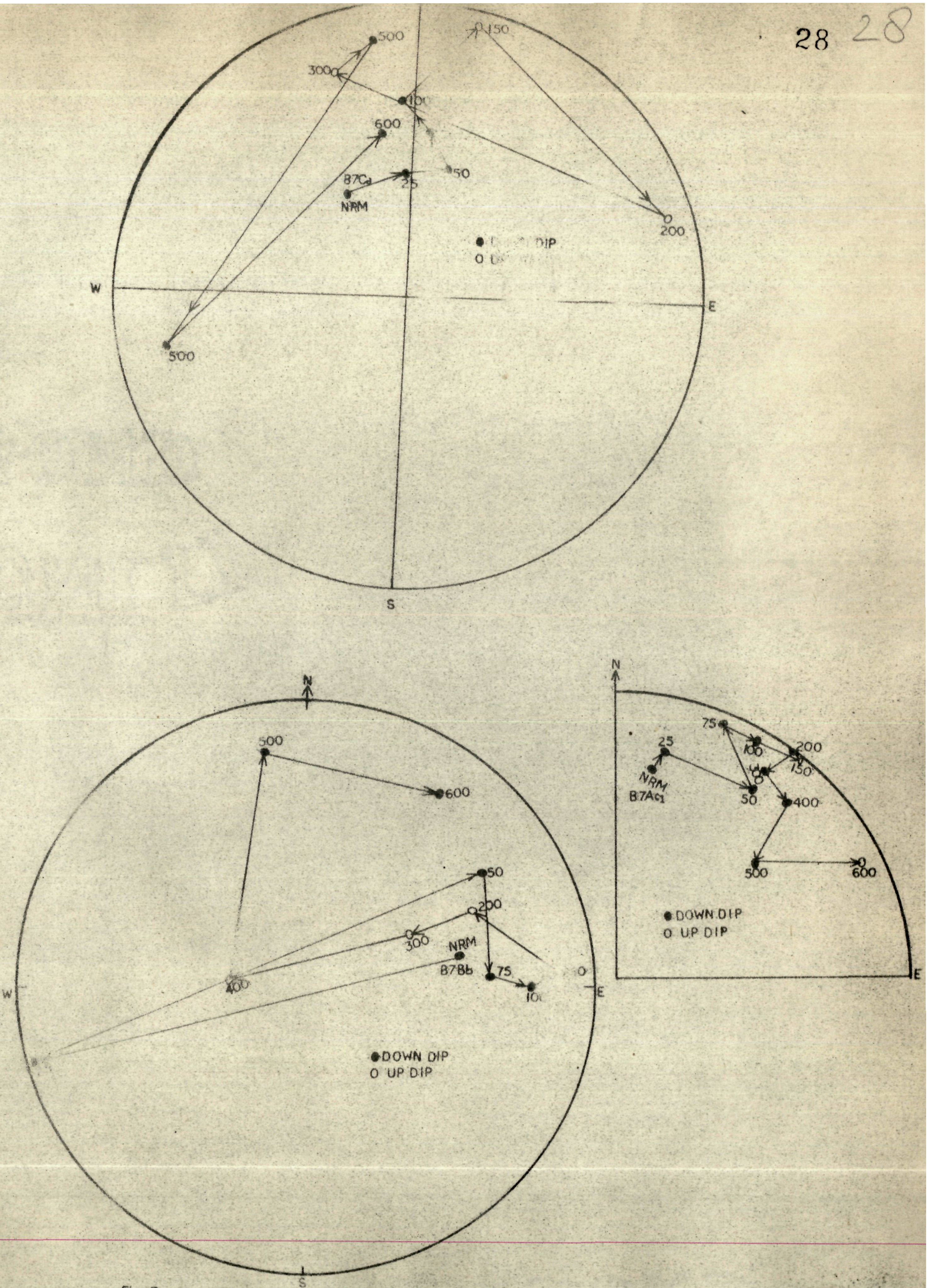


Fig. 7
EQUAL AREA PROJECTIO[illegible] [illegible]WING CHANGES IN DIRECTIONS OF MAGNETIZATION AFTER CLEANING IN [illegible] PEAK A.C FIELDS FOR SPECIMENS OF SITE 7

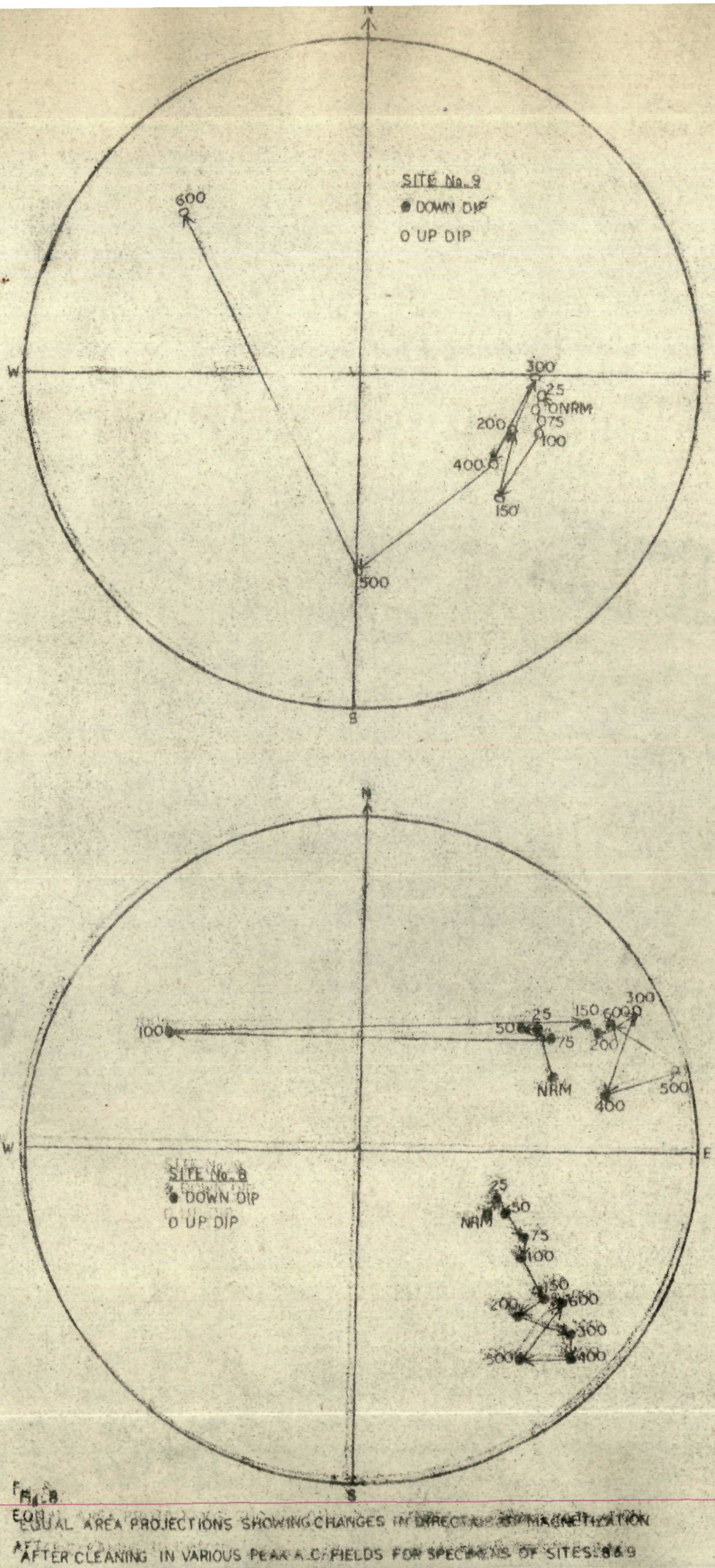


FIG. 8

EQUAL AREA PROJECTIONS SHOWING CHANGES IN DIRECTION OF MAGNETIZATION AFTER CLEANING IN VARIOUS PEAK A.C. FIELDS FOR SPECIMENS OF SITES 8 & 9

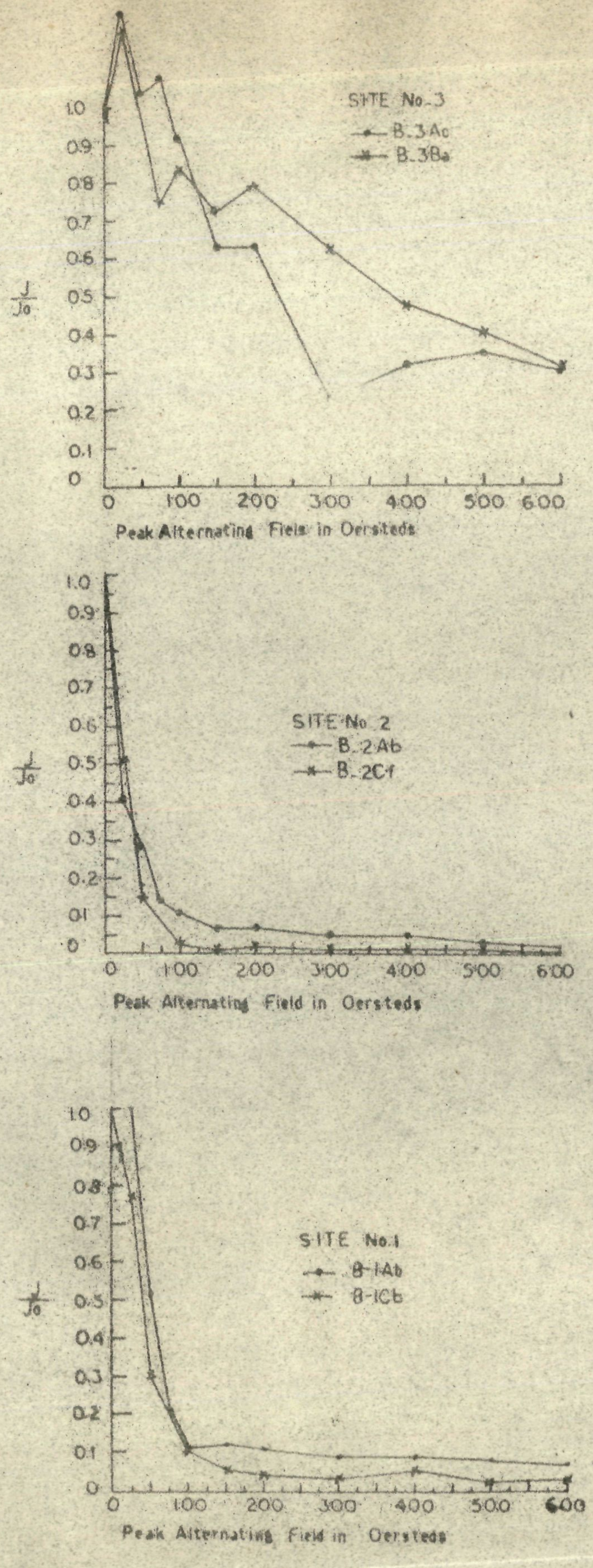
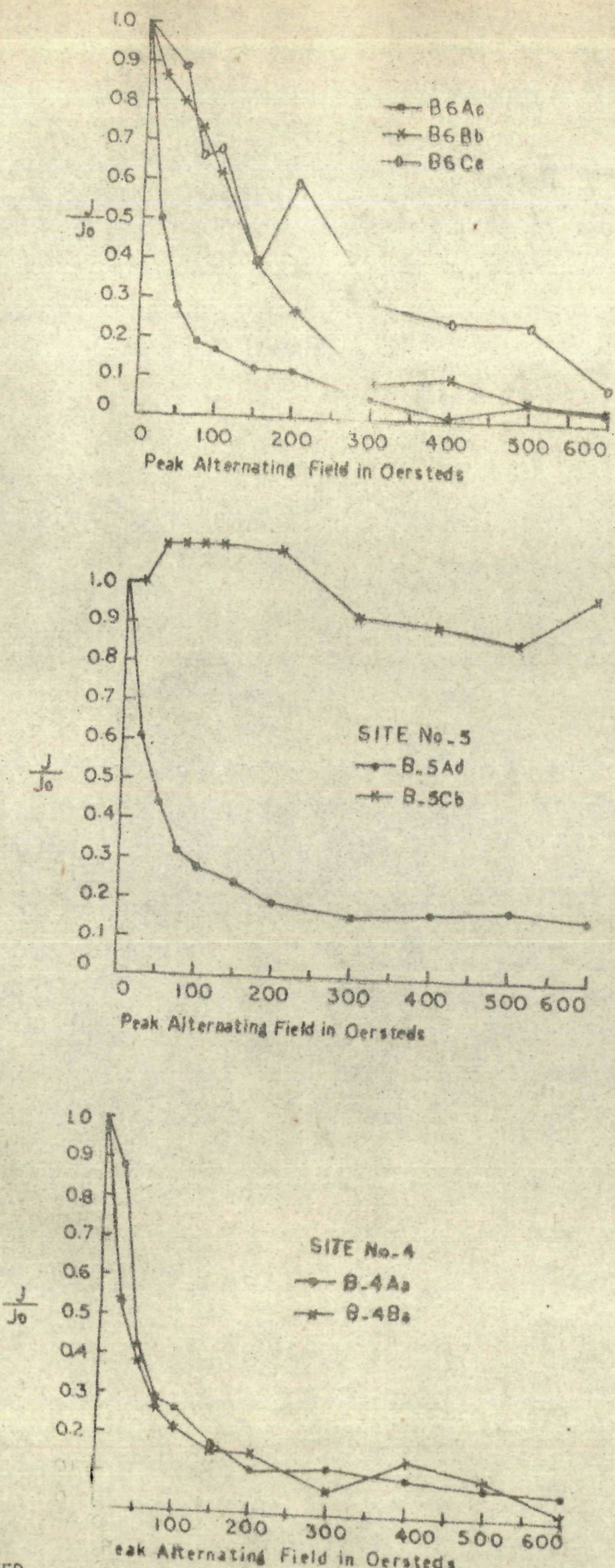


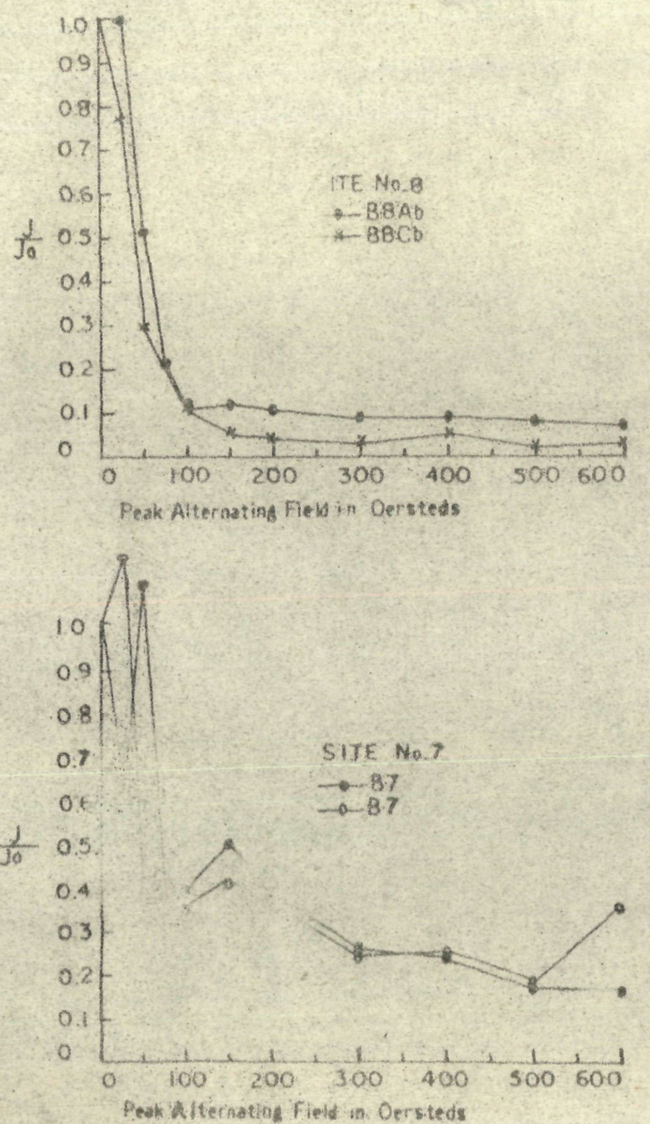
Fig No. 9

NORMALIZED A-C DEMAGNETIZATION CURVES FOR TYPICAL SPESIMENS OF SITES No. 1-2 &3



NORMALIZED ... MAGNETIZATION CURVES FOR TYPICAL SPECIMES FROM SITE No's.-4.5.6

FIG No. - 10



NORMAIZED A.C DEMAGNETIZATION CURVES FOR TYPICAL SPECIMENS FROM SITE No's. 7, 8, & 9

Fig. No. 11

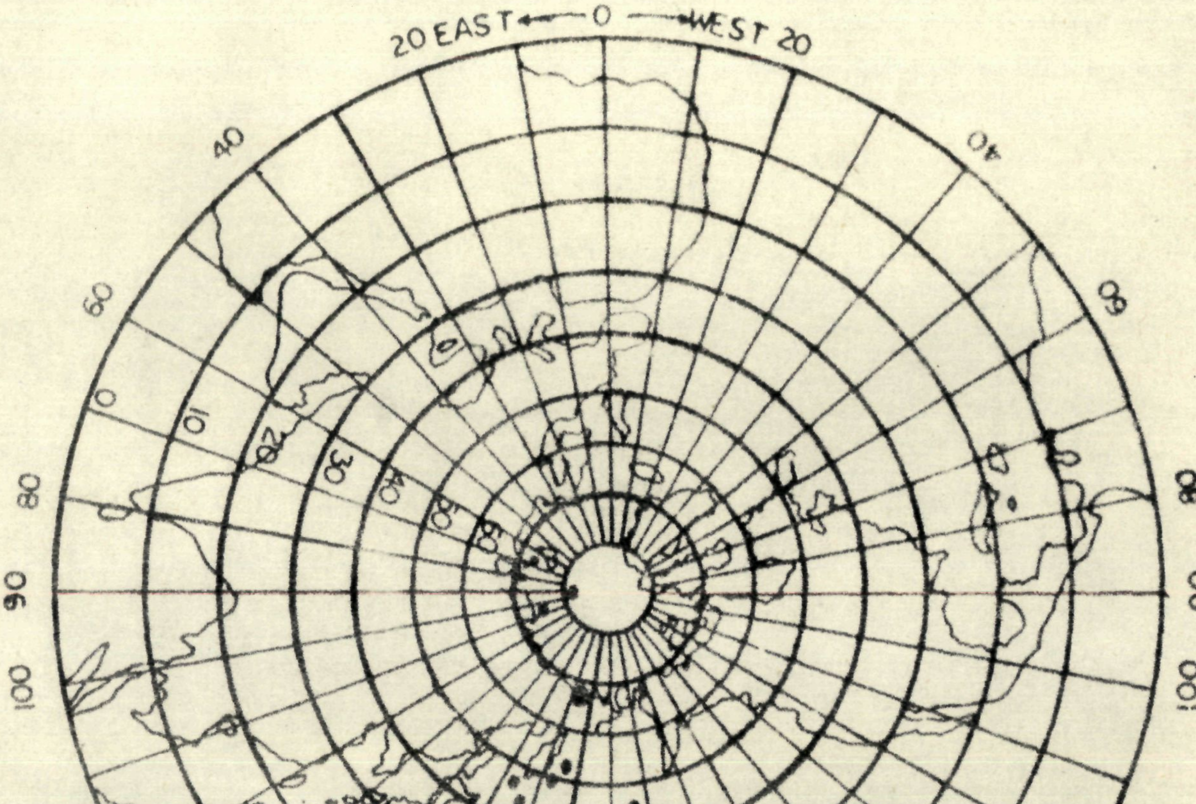


Fig - 2
STEREOGRAPHIC PROJECTIONS OF PALAEOPOLES AND
VIRTUAL GEOMAGNETIC POLE (VGP)

PALAEOMAGNETIC PARAMETERS OF BHOWALI VOLCANICS

SITE NO.	n	Uncorrected Dm	Im	K	95	R	Treatmen	V.G.P P	LP	P	m
								North Pole			
1	10	305	- 13	.9783	44.87	.80068	100 Oersted	28.30N	144E	23.185	45.705
2.	16	70	+ 30	.9938	8.804	.906	50 Oersted	25°N	164E	5.43	9.78
3.	6	13	+ 42	1.00	57.14	1.0017	100 Oersted	76.61N	104E	70.58	43.62
4.	5	128	+ 47	.994	62.77	.978	NRM	44.8 N	157E	52.74	81.38
5.	7	325	+ 3	.972	53.65	. 83	200 Oersted	46 N	187E	26.84	53.7
6.	5	2	+ 56	.997	62.68	.990	100 Ee	62N	91 E	90.0	64.7
7.	6	286	+ 50	. 95	58.61	.741	50 Oersted	47N	154 E	52.06	78.15
8.	5	40	+ 38	.977	28.33	.906	50 Oersted	53N	166E	20.195	34.02
9.	6	45	- 43	.986	23.65	.931	50 Oersted	50N	164E	18.04	29.31
MEAN		24	+ 48	25.99	9.15	.692		68 N	162E	7.83	11.976

N = No. of specimens
Dm= Mean Declmati n
Im= Mean Inclina ion
K = Precision Parameter
R = Length of Resultant Vector

P = Latitude of Paleopole
LP = Longitude of Paleopole
P & m = Ovals of confidence about the virtual pole position.

Chapter - IV

RESULTS AND DISCUSSION

The natural remanent magnetization direction measured on nine sites from the Bhowali volcanic suits. To which Vardharajan et. al. (1974), Rao et. al. (1975), Shah and Mehr et. al. (1978) suggests the volcanic to be of splitic in nature. The specimens of each site were cleaned progressively by the A.C. demagnetization set up from 25 oersted to 600 oersted peak fields to check the stability of the natural remanent magnetization. However the sites 8 and 15 shows erratic behaviour under A.C. cleaning, and therefore it has been rejected.

The A.C. cleaned plots have been shown in Figure -3 and 4. The A.C. cleaned plots from site No. 1 and 9 show up dips, where as the remaining sites show down dips. Mean declination and inclination have been computed and the data is given in table No.1. The intensities show a decreasing trend as seen in Normalised A.C. Demagnetization curve (Figure No. 9 to 11) which implies that the magnetization is weak, in the rocks.

Neverthless the sites 4 and 7 show the reverse magnetization. The vertual Geomagnetic pole were calculated from the mean stable direction and were plotted on stereonets. p and v were also computed for knowing the degree of freedom.

The stable magnetisation direction by various stability tests as shown in Chapter-III. Out of nineteen sampling sites nine has stable remanent magnetization direction.

The stable mean magnetic direction for all the sites are given in table No. 1. Using (Fiscers 1953) method the mean, radius of 95% confidence which represent the precision (95). The precsion parameter (K) was calculated for all the sites after cleaning the remanent magnetic directions of nine sites form a cluster away from the present Geomagnetic field. This good argument indicates that scatter within a site is small. And hence an statistically significant mean could be obtained. The mean remanent magnetic directionf for various sites given in table No.1 show that all have stable directions.

Out of nine sites site No. 1 and 9 show up dip where as the remaining sites show down dips. However the sites 4 & 7 show reverse magnetization. From the stable natural remanent magnetization direction the paleolatitudes of all the nine sites were computed (table No. 1) and are plotted on steriographic projection (Figure No.2). The pole position inferred indicates that the India was in the southern hemisphere during the time of volcanic erruption. However geologically it is also relevant that India was a member of great Gondwana configuration during Carboniferous period. It is further recomended that an exhaustive Paleomagnetic studies from more areas in the himalayas should be carried out to investigate this contention. Although present studies is rather limited in the sence that only nine sampling sites were analysed from one locality. It does seem to bring about the importance of such studies in Himalayas for assertaning the age of the volcanic suite.

Also Petrochemistry of these basic rocks shows that they are spilites and following Kuno (1968), Marata (1960) and Kumo (1957) methods these rocks was found to be in Tholeiitic field. Which reveals that they evolved from Tholeitic magma.

Chapter - V

PETROCHEMISTRY

V-1. Techniques And Methods Used For Analysis:

Eight samples of Bhowali volcanics of Bhimtal area was analysed by rapid method of silicate analysis at the Department of Geology, Aligarh Muslim University, Aligarh. For this purpose sepectrophotometer, Flamephotometer and other instruments were used. SiO_2, Al_2O_3, TiO_2, total Iron as Fe_2O_3, P_2O_5, and MnO were determined by spectrophotometer by developing coloured ions of the respective elements and measuring their absorbance on the following selected wave lengths.

	Oxides	Wave length	sensitivity
	SiO_2	640 mu	Red
	Al_2O_3	475 mu	Blue
	MnO	552 mu	Blue
	TiO_2	400 mu	Blue
Total	Iron (Fe_2O_3)	56 mu	Blue
	P_2O_5	420 mu	Blue

For eliminating error due to possiblèe reagent contamination a reagent blank was set up with distilled water for each set of determination.

Potash and soda were determined on a Flame photometer. The instrument is an assembly of a compressor, gas pressure, regulators, an amplifying unit, a voltage stablizer, a burner with a flame igniter all housed in one compact unit. The instrument makes use of the principle of emission spectra for elements excited by flames of the gas burner. As the solution is atomized into the flame, it is instantly coloured due to the dominance of selective wave length in the energy emitted by elements concerned. It is seen that sodium flame is golden yellow, while that of potassium is lilac. The emitted energy is focused into the photocell by the concave mirror and condensing lense through a bitter that isolates the proper wave length. The resulting photo current after proper amplification defects the Galvanometer pointer. Measurements are made directly on the Galvanometer scale.

Methods

The methods adopted in the present work were employed by Shapiro and Branock (1952) which was revised by him in 1962.

SiO_2 and Al_2O_3 are determined in a aliquiat of solution "A" prepared by fusion and digestion of a known weight (0.1 gm) of the sample with sixteen pellets of NaOH in a nickle crucide, after cooling the melts were leached with water and the solutions were acidified with 20 c.c. of 1:1 Hcl and boiled for ten minutes on a hot plate then the solutions were made into one litre volume.

Total Iron as Fe_2O_3, P_2O_3, TiO_2, MnO_2, were determined spectrochemically on separate aliquat of solution "B" prepared by digestion of a known weight (.5gm) of a sample in platinum crucible with concentrated Hydrofluaric acid (25-30 ml), and/ one or two drops of H_2SO_4 over a steam bath, when the sample was completely dried 10. c.c. of dilute HNO_3 was added to it and washed thoroughly. With the crucible for fifteen minutes. After cooling of the solution it was made to 250 ml.

Alkalies were determined from an aliquat of the above solution "B" on a Flame photometer. FeO was determined separately by digesting a known weight (5 mg) of the powder with Hydrofluoric acid in a platimum crucible with a tight fitting lid and subsequent titration against standard potassium dichromate solution. CaO and MgO were also determined by separate aliquat of the above solution by titration against EDTA an on automatic titration unit.

H_2O was determined by ignition of sample in a tube.

V-2. Standard used in the present work:

In the Geochemical work a high degree of precesion is a prerequisite from drawing any sub-stantial conclusion. With this object in view, natural and synthetic standards were used in present work.

The Natural standards represented by BCR-1, AGV-1, were run with each batch of analysis, besides these standards several synthetic standards for various oxides were prepared. All the standards were treated in the same way as the unknown samples. Standard samples of BCR-1 and AGV-1 were prepared in a manner discribed earlier, under the preparation of solution "A" and "B". The synthetic standards used in7this work were as follows

Fe_2O_3: The standard used for the determination of total Iron as ferric oxide was ferrous Ammonium sulphate (strength 10%). A separate standard was prepared for FeO determination.

MnO: A known weight (1.2 gms) of Manganese oxide was dissolved in 25 ml of 1:1 Nitric acid and 2 ml of Hydrogenper oxide. Digested on a steam bath and to it was added 50 ml of 1:1 H_2SO_4 and dissolved. It was evaporated till sulphur dioxide burns were removed, then it was cooled and was made to 250 ml volume. Then

5 ml was taken having a strength of 0.5% MnO.

<u>P_2O_5</u> Calcium phosphate (0.0878 gm) were dissolved in a 50 ml of 1:1 HNO_3 and was digested on a steam bath to make 1000 c.c. (strength 0.5% P_2O_5).

<u>TiO_2</u> Titanium oxide 0.32 gm was mixed with sodium bisulphate (3.2 gms) and the fused mixture was dissolved in sulphuric acid. The solution was kept in a coloured bottle and used as standard for Titanium (strength 2%).

<u>CaO and MgO</u> Weighed exactly 3.7225 gms of disodium salt of EDTA in one litre of distilled water.

<u>K_2O and Na_2O</u> For the determination of Na_2O and K_2O a series of standards containing 0.5, 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 8.0, and 10.0% pure dry NaCl and KCl were kept respectively in bottles. Lithium sulphate was used as an internal standard for both Na_2O and K_2O.

Before using any chemical for the preparation of these standars, the blank was predetermined and necessory correction factor was found out.

PETROLOGY

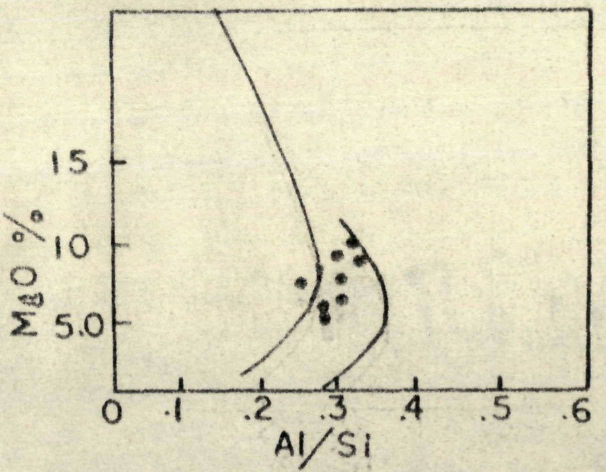
The basic rocks of Bhimtal area, which have been suggested basalts of spilitic nature by Rao et al. (1074), Vardrajan (1974), and Shah and Mehr (1970).

They are greyish green, green, and dark green in colour and of fine to medium grained which are cleaved at many places and at some places the deformation has gone to such a extent that the original nature is not recognisable. The spilites of Bhimtal and Bhowali area has been described as spilitic diabase, spilitic basalts and spilitic tuff by Shah and Mehr (1970). The basic rocks has vesciles and Amygdules. The amygdules are occupied by calcite chlorite, chacedomy. These rocks occur in the form of flow.

Under the microscope most of their sections observed show intersertal texture. A few sections also show ophitic and sub ophitic texture.

Mineralogically they are composed of plagioclase, chlorite, quartz, Augite, Uralite, epidote, sphene, and olivine.

Plagioclase is of composition which occurs in the form of laths which are altered mostly to albite and are embedded in a matrix of fine grained altered Augite. The



Murata 1960 Variation diagram of basicrocks Bhimtal area.

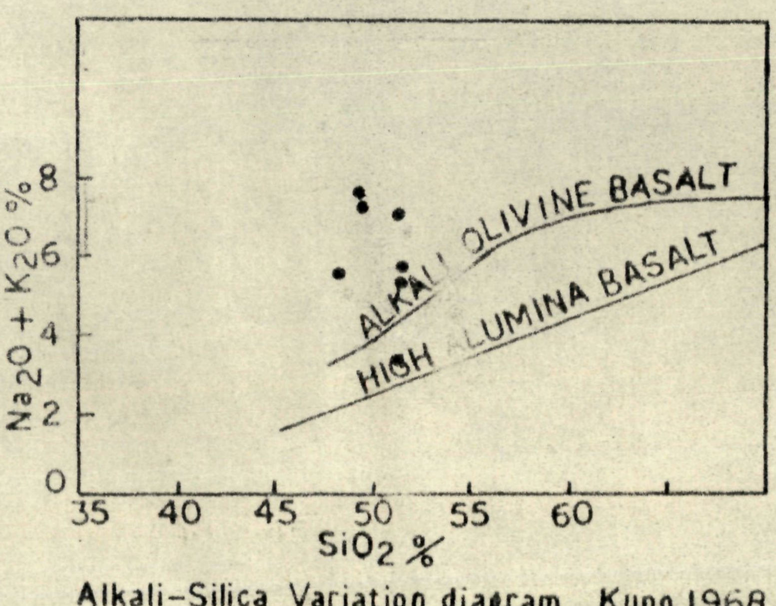
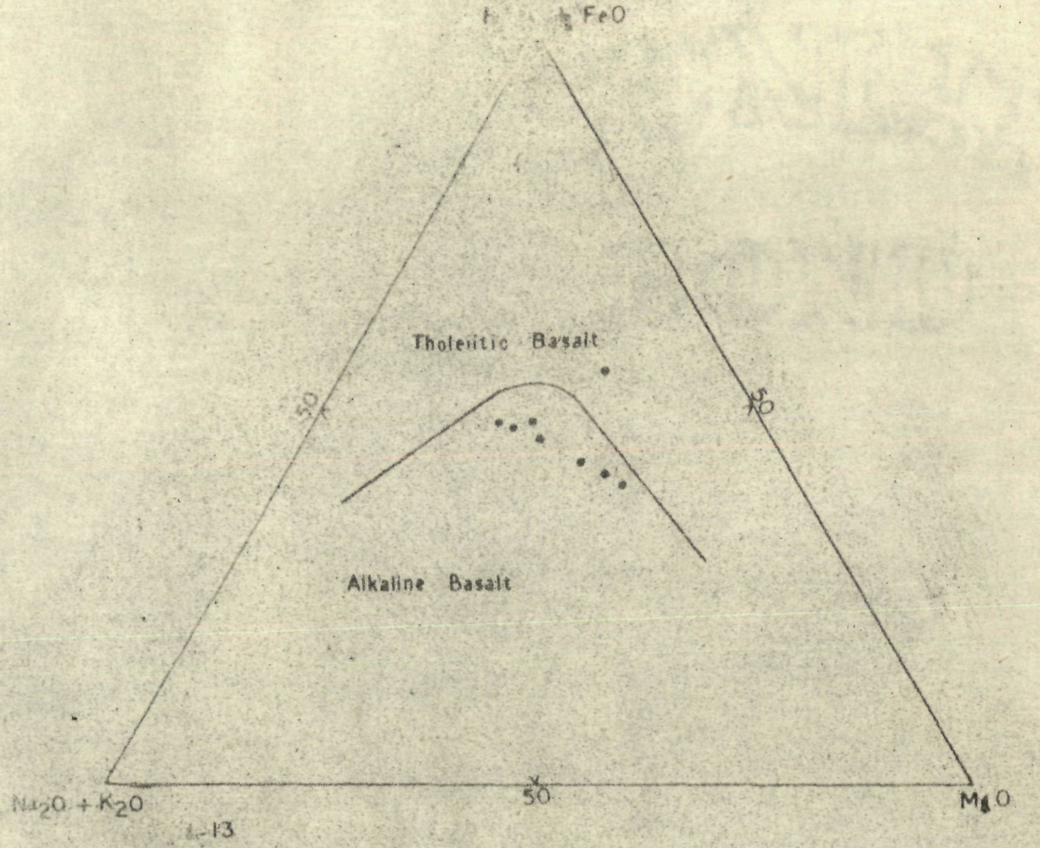


Fig - 12 Alkali–Silica Variation diagram Kuno 1968 of Basic rocks of Bhimtal area.



-13

FA Variation diagram of Basic rocks of Bhimtal area.

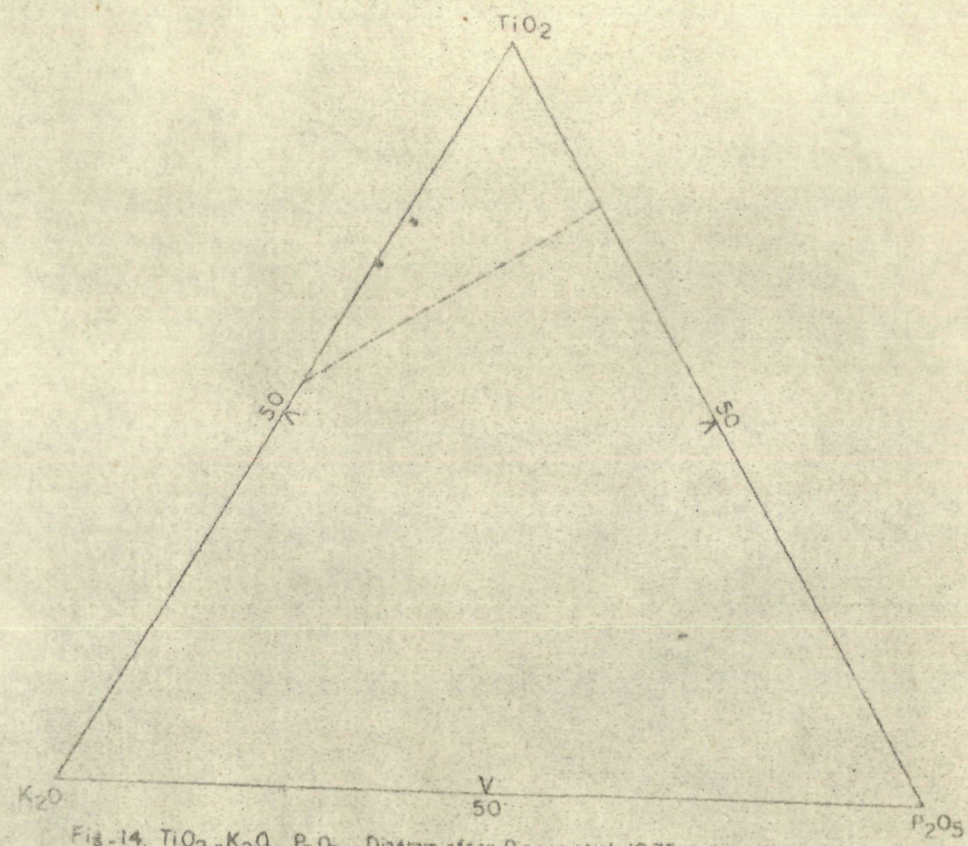


Fig.-14. TiO_2-K_2O- P_2O_5- Diagram after Pierce et al. 1975 of the Basic r rocks of Bhimtal area.

Augite has altered to chlorite and in a few sections to Uralite. And the alteration is partial because of which the original ophitic and sub ophitic texture is seen. The interspaces are occupied by Augite. In some sections the plagioclase also occure as phenocrysts in a matrix of lath like feldspar with or without intersertal Augite. And in a few sections the occácular character of plagioclase lath is also seen. As also the sodic character of Plagioclase is maintained in all the sections observed under the microscope. In a few sections plagioclase also occure as euhedral elongated crystals.

A few grains of divine and fine grained opaques are also present.

PETROCHEMISTRY

The chemical composition of eight samples for basic rocks of Bhimtal area are represented in Table (2) in terms of major oxides. Each sample taken for petrochemical study represent a site chosen for Palaeomagnetic analysis. Average chemical composition and range of variation of the major oxide is given in Table-3.

Silica which plays an important role in the determination of different rock types varies from 48.43 to 53.03% with an average of 51.10%. But Al_2O_3 in all the samples is almost

Table - 2 Chemical Composition of Bhowali Volcanics

Oxides	1	2	3	4	5	6	7	8
SiO_2	50.30	49.40	49.50	51.96	54.20	48.43	52.01	53.03
Al_2O_3	15.07	15.10	15.18	14.98	16.62	16.07	15.08	16.[illegible]1
FeO	7.0	10.79	11.04	11.94	8.30	10.34	10.43	9.31
Fe_2O_3	4.23	2.46	1.35	1.19	0.89	0.49	1.94	0.91
CaO	5.97	5.01	5.04	3.26	2.12	4.70	2.24	2.21
MgO	6.23	6.94	6.96	7.26	9.33	8.27	6.08	9.12
Na_2O	4.33	5.86	5.94	2.64	4.08	3.82	5.50	4.79
K_2O	0.91	1.43	1.49	0.63	0.41	1.14	1.68	0.50
TiO_2	2.51	1.35	1.40	2.13	0.83	1.30	1.50	1.51
P_2O_5	0.07	0.05	0.03	0.04	-	0.35	0.04	0.11
H_2O	3.36	02.63	2.75	3.54	3.80	0.09	3.39	2.93
Total	100.58	100 .98	100.70	99.59	100.58	99.61	99.89	100.83

Tab-le - 3 <u>Range of variation of major oxides</u>

Oxides	Variation of Oxides in %	Average in %
SiO_2	48.43 - 53.03	51.10
Iron Oxide	9.19 - 13.25	11.57
Al_2O_3	14.98 - 16.62	15.56
MgO	6.08 - 9.33	7.52
CaO	2.12 - 5.97	3.82
TiO_2	0.83 - 2.51	1.56
Na_2O	62.64 - 5.86	4.69
K_2O	0.41 - 1.74	1.09
H_2O	2.63 - 3.80	3.31

the same with an average of 15.56%. Iron oxide varies from 9.19 to 13.25% with an average of 11.57% and similarly MgO and CaO varies from 6.08 to 9.33 with an average of 7.52% and 2.18 to 5.97 with an average of 3.62% respectively. Average Alkali content is 5.78% with a high percentage of soda and very low percentage of potash.

The following variation diagram and Geochemical calculation have been used to know the type of rock and nature of the magmage

In order to distinguish three type of Basalts that is Tholeitic Basalts, High Alumina Basalts, and Alkali Olivine Basalts.

Kuno (196) plotted $Na_2O + K_2O$ against SiO_2 and distinguished three fields in the Alkali-Silica diagram to show Tholeitic Basalt High Alumina Basalt and Alkali Olivine Basalt. The $Na_2O + K_2O$ for Basic rocks of Bhimtal area is plotted against SiO_2 in Figure-12, where two point fall in the high alumina Basalt field and the rest fall in the Alkali Olvine Basalt field which suggests the rock to be Alkali Olivine Basalts, but it is important to mention here that this is due to the higher and abnormal percentage of Alkalies.

Table - 4, Values of Magnesium Oxide, Iron oxide and Alkalies in MFA diagram

S.NO.	MgO	Fe_2O_3 + FeO	Na_2O + K_2O
1.	26.8	48.2	25.1
2.	25.2	48.3	26.5
3.	25.9	46.30	27.7
4.	30.60	55.5	13.8
5.	40.5	40.0	19.5
6.	33.6	43.9	22.5
7.	23.7	48.2	28.0
8.	37.0	41.5	21.5

Murata (1960) plotted Si/Al ratio against MgO to distinguish different types of basalts. Following Muratas method Si/Al ratio against MgO is plotted in Figure 12 where most of the points are within the field of Tholeites. So it can now be said that in the Silica Alkali diagram of (Kuno 1960) the rocks of Bhimtal area show an Alkali Olivine basaltic nature which is due to high and abnormal value of $Na_2O + K_2O$.

The MFA diagram (where "M" stands for MgO, "F" for Fe_2O + FeO and "A" for Alkalies) also invisages a tholeitic nature. The values of MFA are given in table 3 and the plots are shown in Figure 13.

Kuno (1957) also distinguished the nature of the magma by a using (Fe_2O_3/ FeO ratio) and found the ratios to be 0.5 t and 0.3 for Alkaline and Tholeitic basalts respectively. The Fe_2O_3/FeO ratio of Volcanics of Bhimtal area is (.17) sug esting a Tholeitic nature rather than an Alkaline nature of the magma.

To descriminate the oceanic and Non Oceanic basalts pearce et al (1975) plotted the values of TiO_2, K_2O and P_2O_5 only for those rocks having less then 20% Alkali in MFA diagram. Following the same method values of two samples were plotted given in Figure 14 and both of them fall in the oceanic field which suggests oceanic origin. for these rocks.

Also the Petrochemistry of Rudraprayag and Garhwal area by Mehshar Raza (M.Phil Thesis) is quite similar to the basic rocks of Bhimtal area, both of them belong to the same rock type and in Rudraperyag area also the Alkali percentage is abnormally higher and comes in tholeitic field of (Kuno 1968) and MFA diagrame and which has been said to be due to higher and abnormal percentage of Alkalies Mehshar Raza (M.Phil Thesis).

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